Evaluation of Mesoscale Events using dual-Polarization and Doppler Radar Observations

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DLR

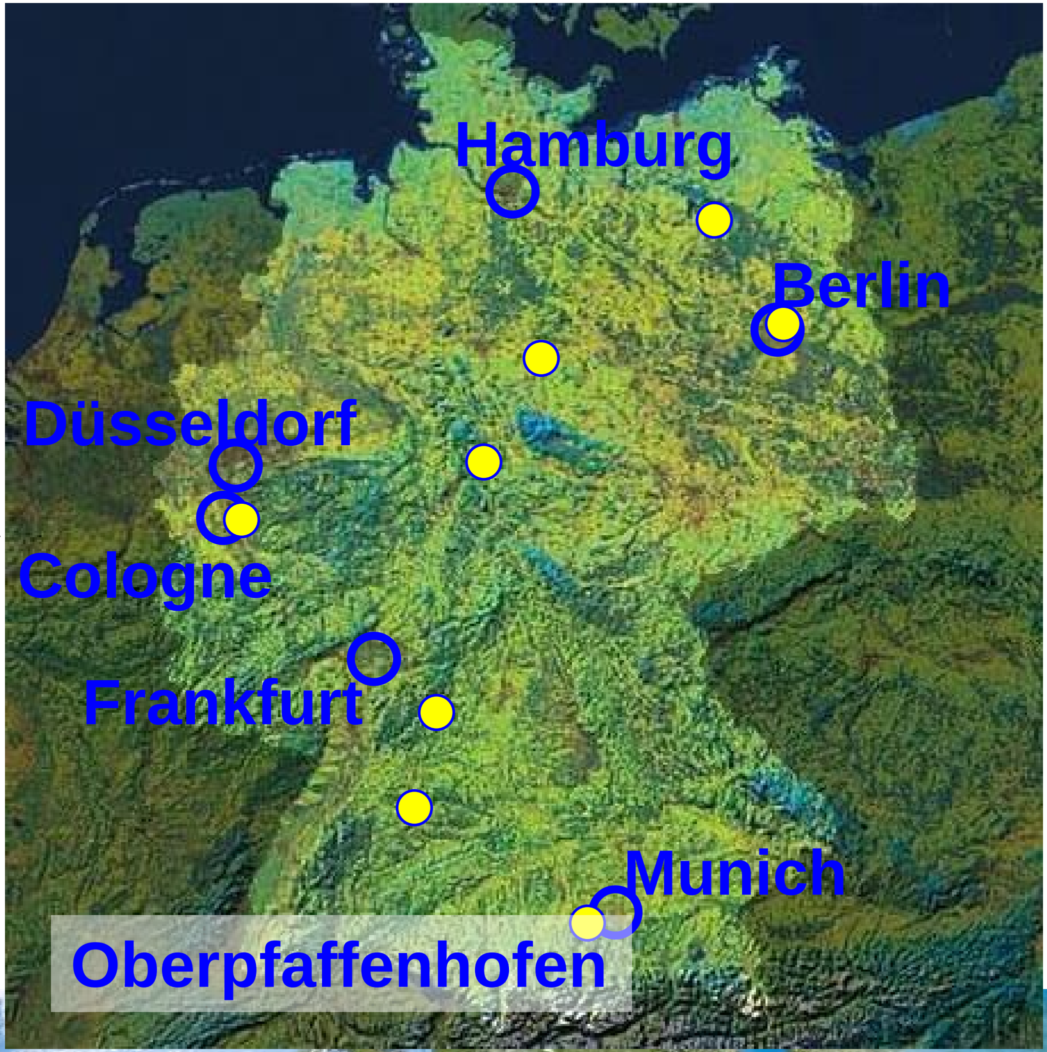
Talk Outline

- DLR's Polarimetric Doppler weather radar POLDIRAD
- Narrow cold frontal rain band
- Orographically induced convective initiation
- Isolated thunderstorm cell

DLR

DLR – German Aerospace Center

- German national research center for aviation and space research. 16 research centers in Germany with about 8000 employees.
  - ~30 research institutes
  - 14 research aircraft
- Institute for Physics of the Atmosphere at Oberpfaffenhofen
  - climate modelling
  - atmospheric physics
  - trace gas measurement
  - remote sensing
  - traffic (aviation) meteorology
  - lidar research



Polarization Doppler Radar POLDIRAD

1986 installed as the first fully polarimetric weather radar in Europe.
Operations for research only, not for operational service

Samples of campaigns:

- Support of hail fighting in the area Rosenheim / Miesbach / Bad Tölz
- Thunderstorm and hail
- Propagation of micro waves
- Aircraft icing
- Vertical transport of pollutants by thunderstorms
- Thunderstorm and lightning
- Wake turbulence
- Aviation and winter weather
- . . .

Technical Characteristics

Frequency	5.5035 GHz
Wave Length	5.45 cm
Peak Power	250 kW
Pulse Rep. Freq.	400 - 2400 Hz
Pulse Length	0.5, 1.0, 2.0 µs
Beam Width	1.0°
Maximum Range	300 km
Products	Reflectivity Doppler Velocity Differ. Reflectivity Depolarisat. Ratio Differential Phase

Uniqueness of POLDIRAD

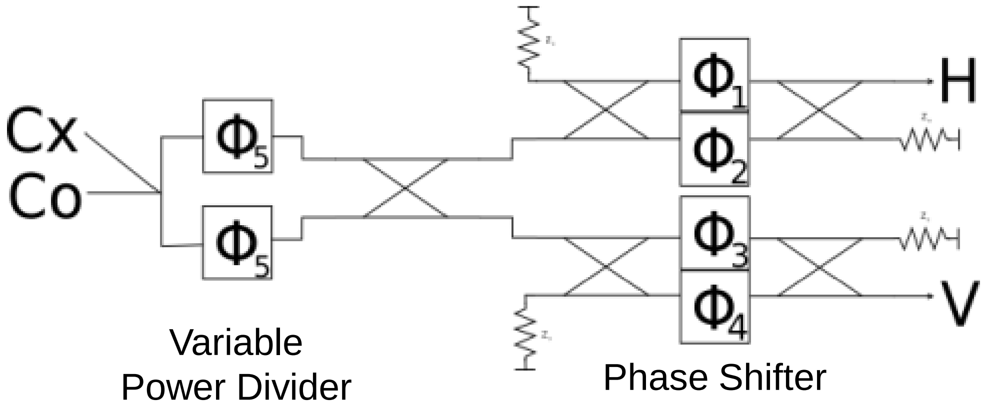
Off-set antenna without radome

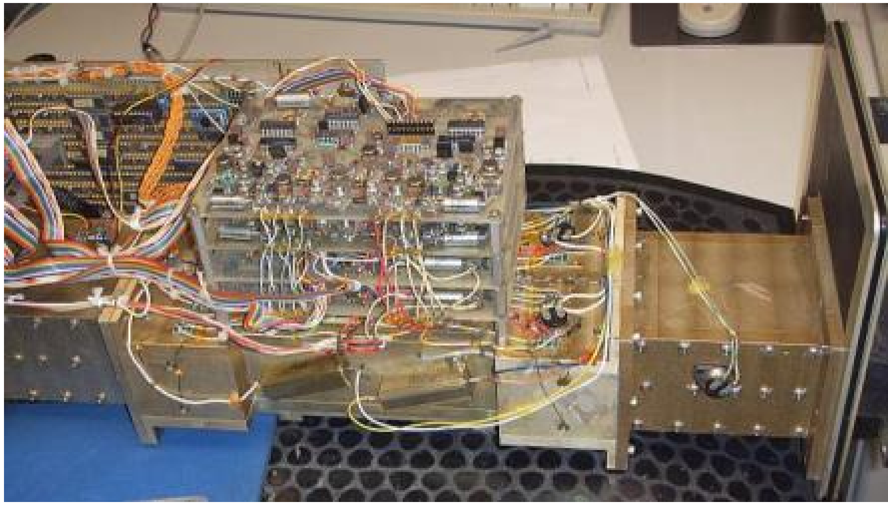
- low sidelobes (app. -32 dB)
- good cross-polarization isolation (app -35 dB or better)
- no influence by radome structure
- no influence by wet or iced radome
- no influence on beam propagation

Uniqueness of POLDIRAD

Ferrite polarization network

- high power 400 kW Tx pulse
- power divider and phase shifter
- any polarization basis possible (co- and cross on receive)
- different for transmit and receive from pulse to pulse
- switching time 8 µs (Tx/Rx)

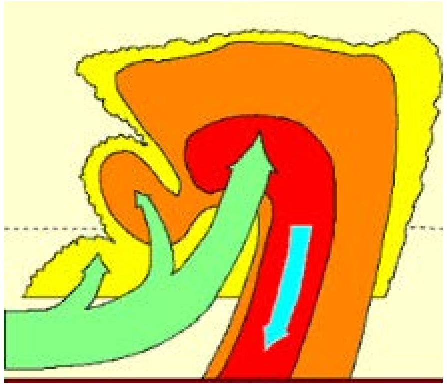




Why Doppler and Polarization?

Dynamics and Microphysics of precipitation

- Precipitation is directly related to atmospheric motion.
  → Hydrometeors are displaced
    → Doppler shift of radar waves



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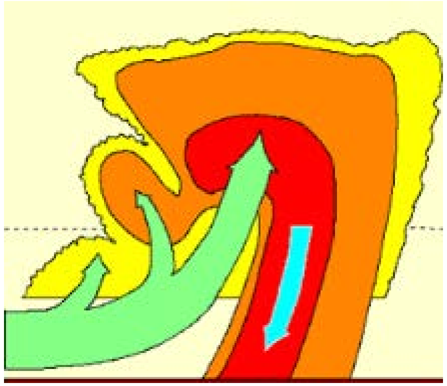
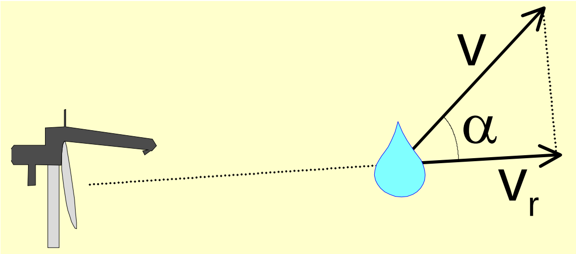
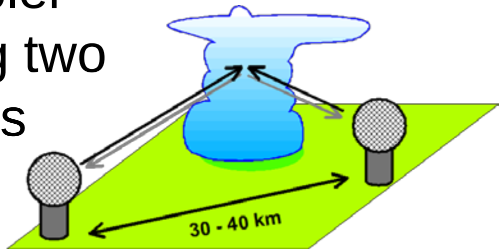


- Doppler radar measures the difference of phase angle between two consecutive radar pulses
- only radial motion can be detected $v_r = v \cdot \cos(\alpha)$



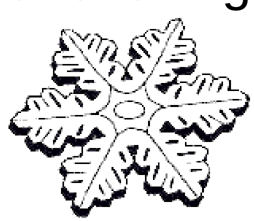
wind estimation using
- single Doppler retrieval
- multiple Doppler retrieval using two or more radars

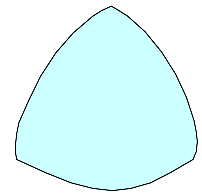


Why Doppler and Polarization?

Dynamics and Microphysics of precipitation

- Cloud and precipitation particles have different shape, phase, size, and falling behaviour




→ scattering properties → different for different polarized waves

Why Doppler and Polarization?

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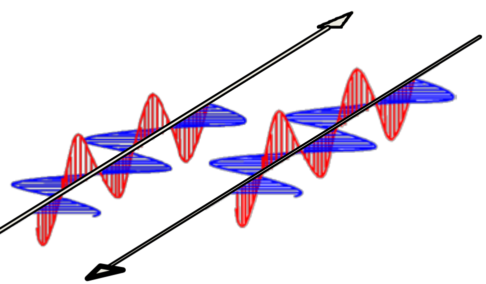
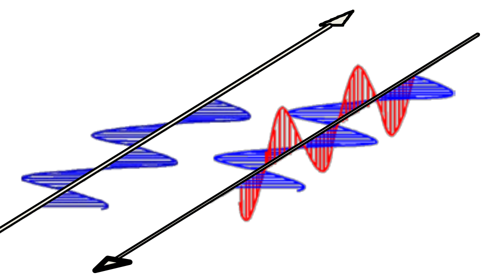
operational weather radar



simultaneous transmit and receive (STAR mode); can't measure depolarization

research weather radar



alternate H and V transmit, simultaneous H and V receive; full scattering matrix

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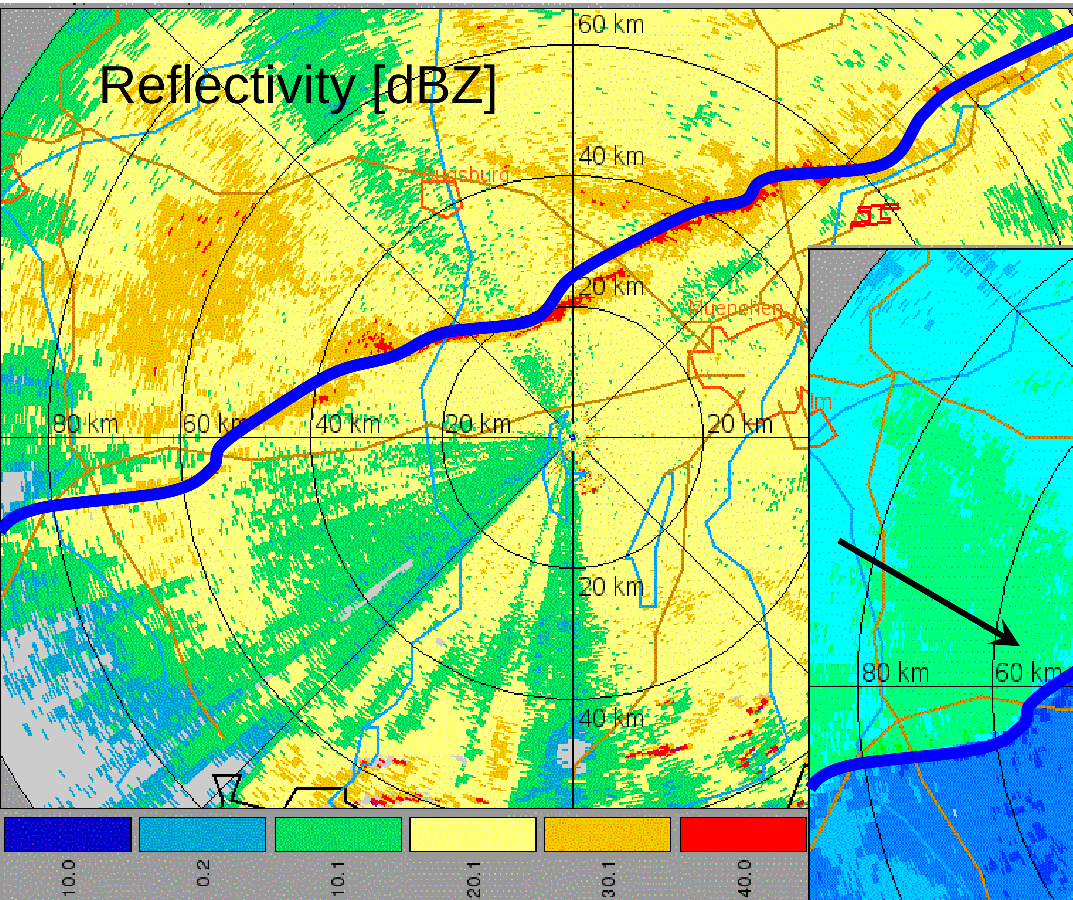
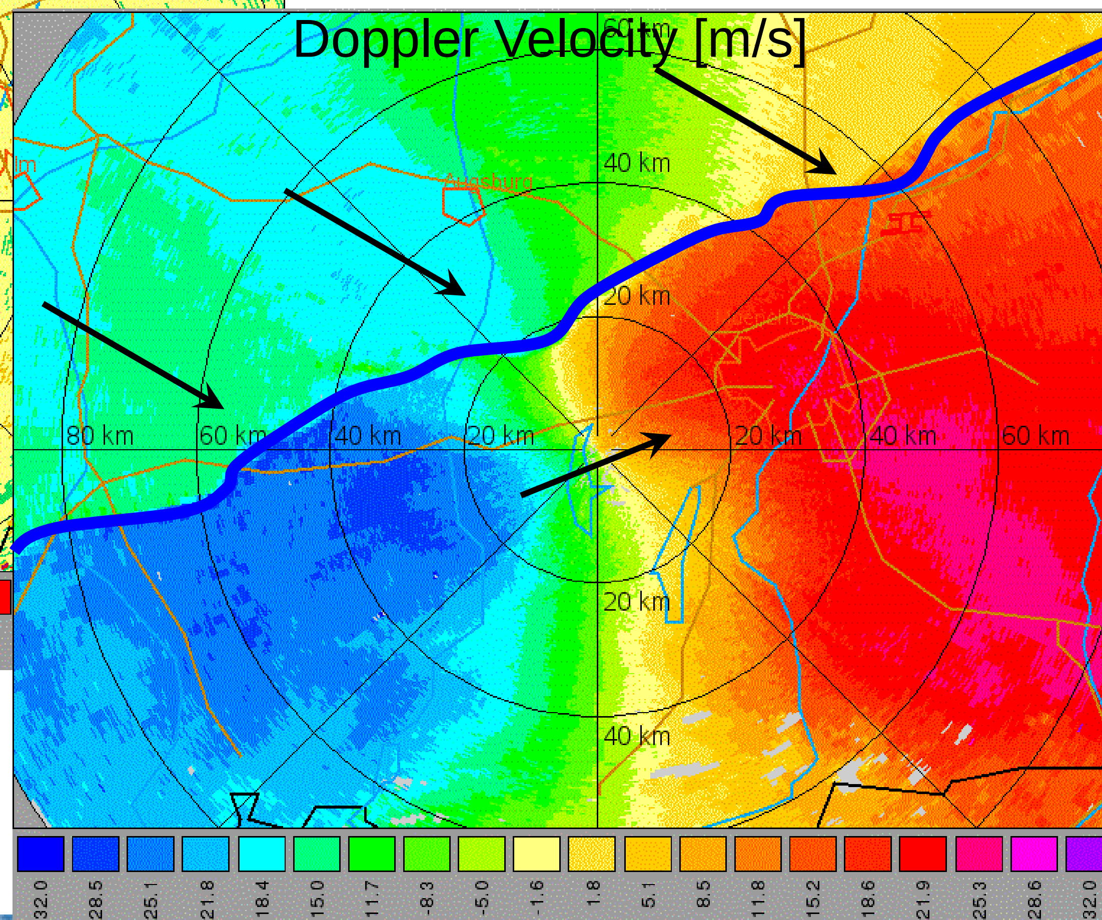
Narrow cold frontal rain band (18/19 Dec. 1987)

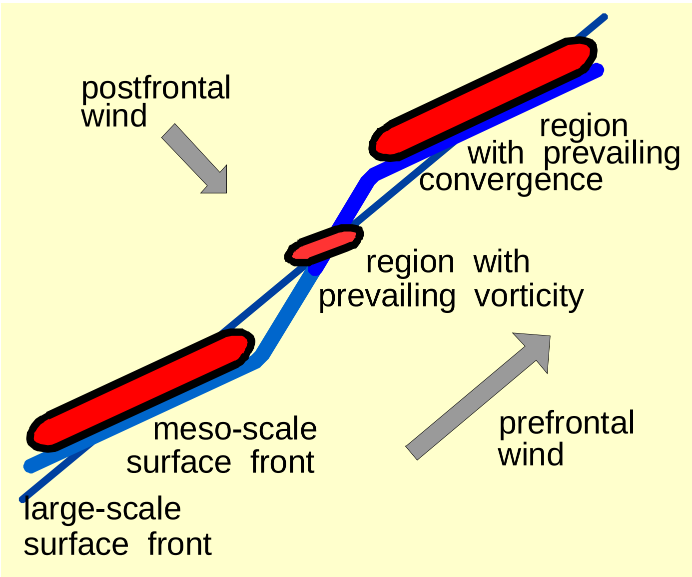


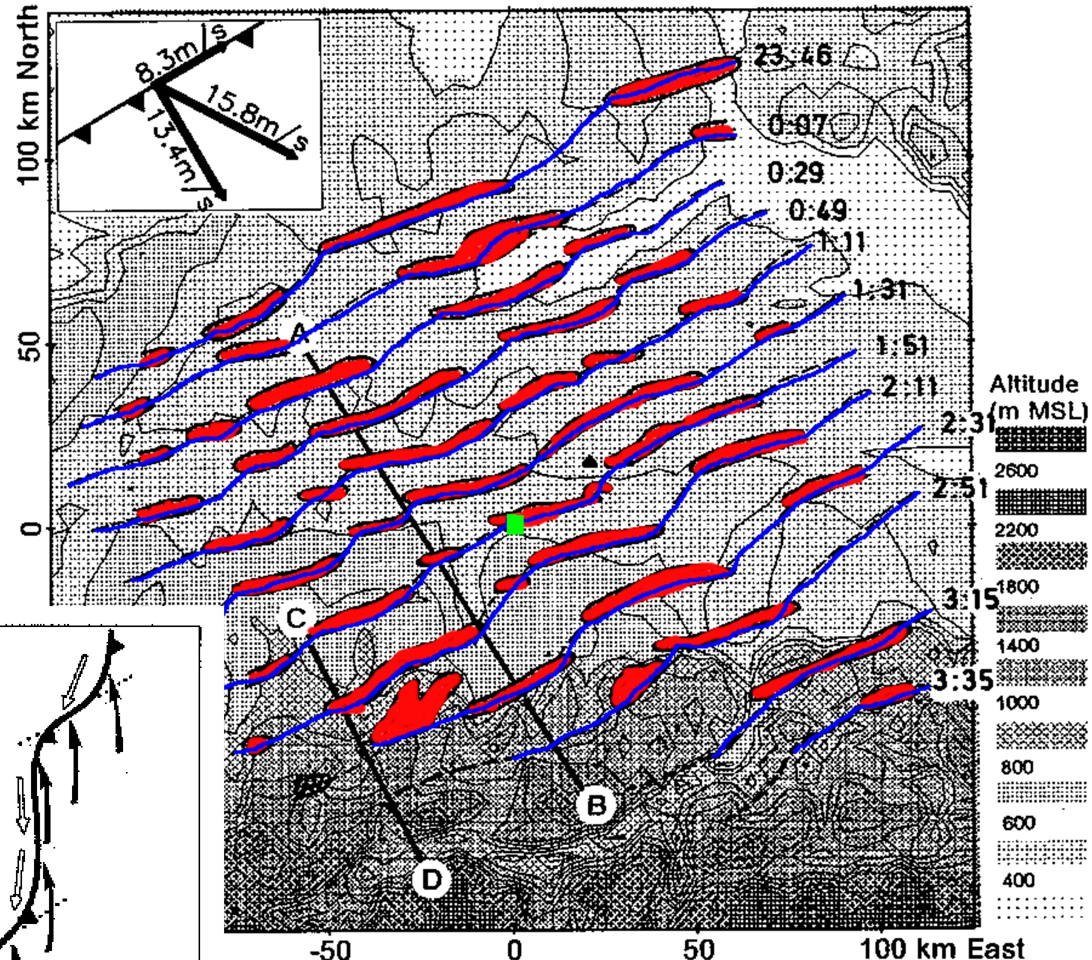
19 Dec 87 0121 UTC
1.0 ° Elevation

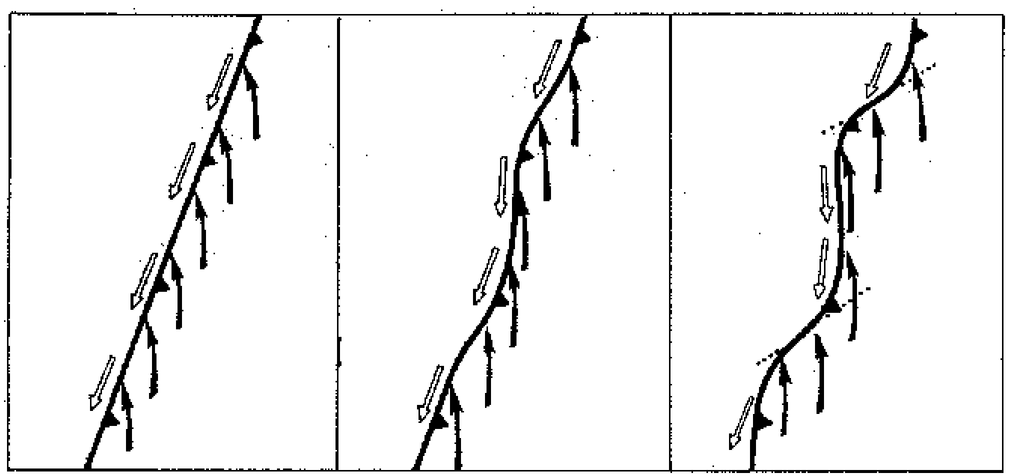


Hagen, 1992

Narrow cold frontal rain band (18/19 Dec. 1987)

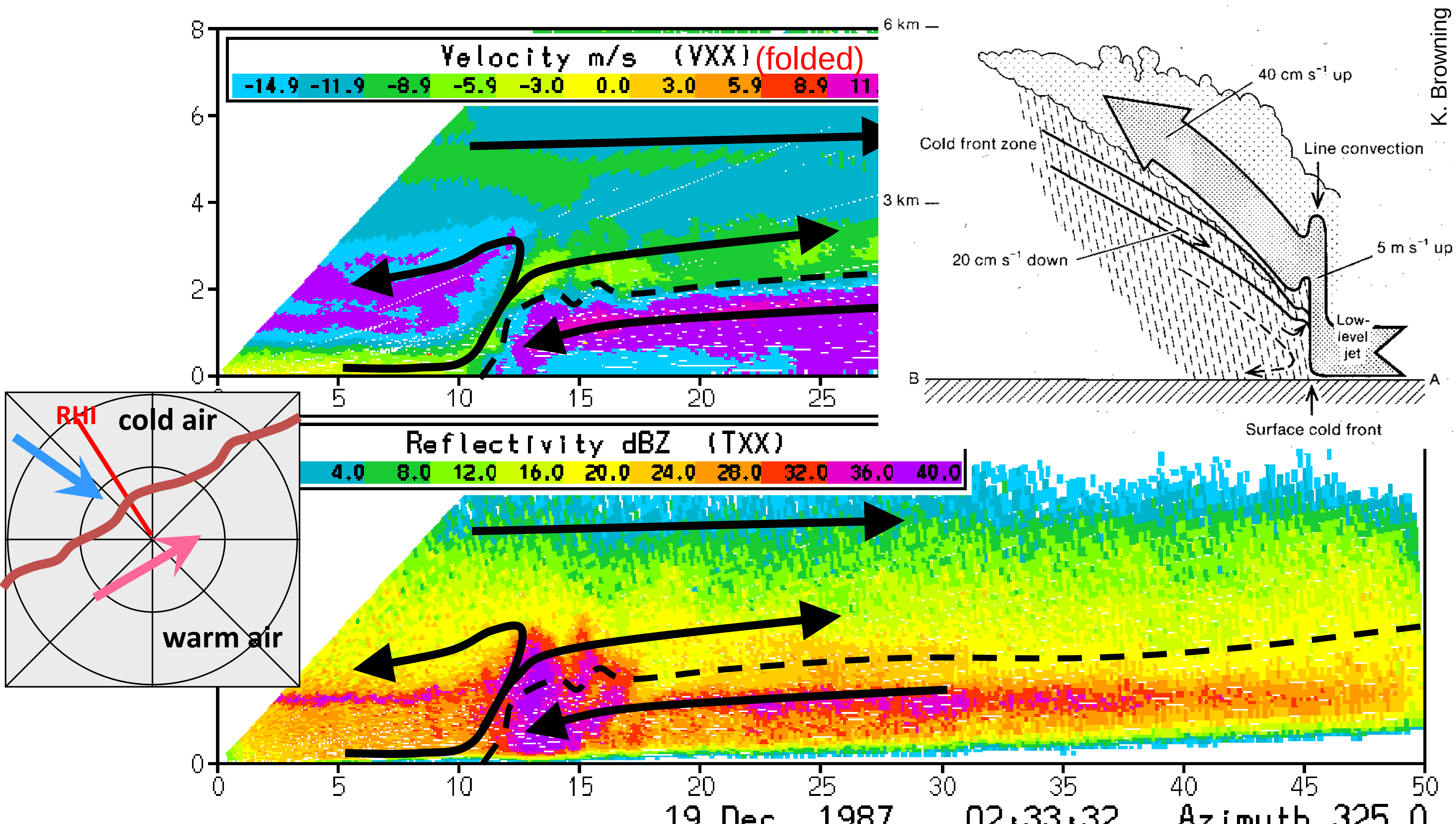





(a) (b) (c)

Hagen, 1992

Narrow cold frontal rain band (18/19 Dec. 1987)



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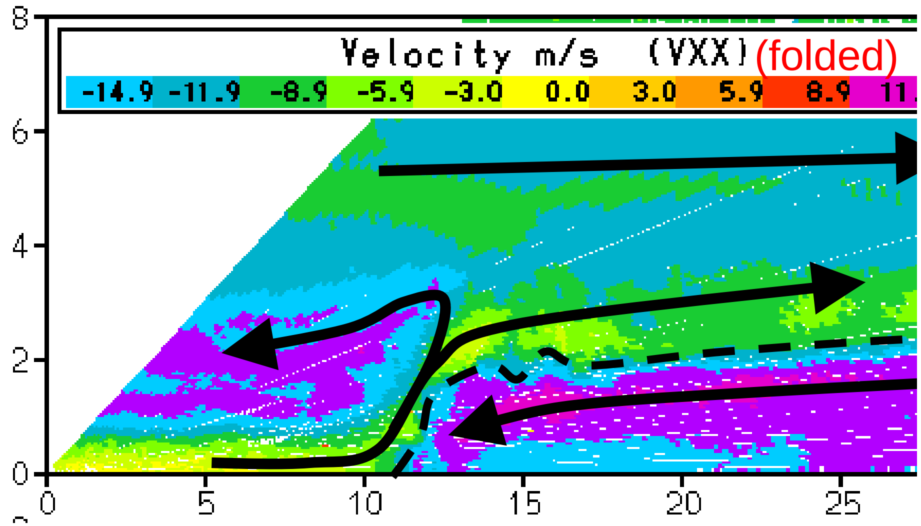
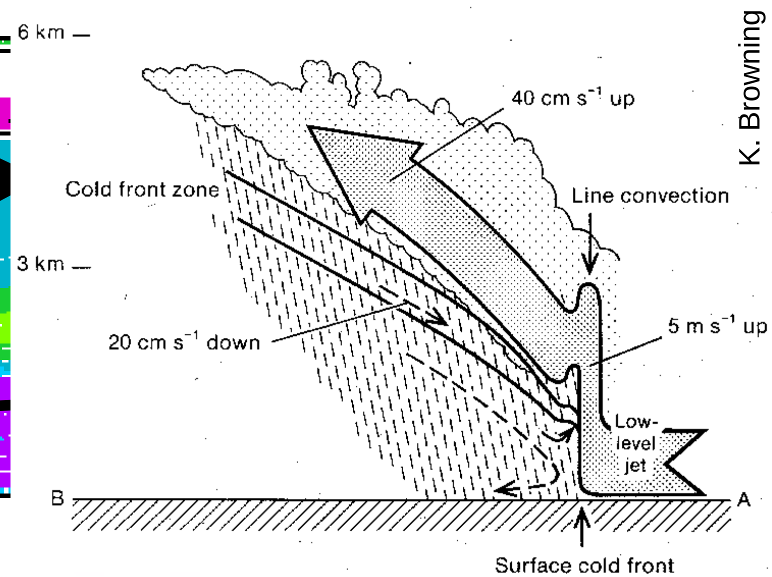
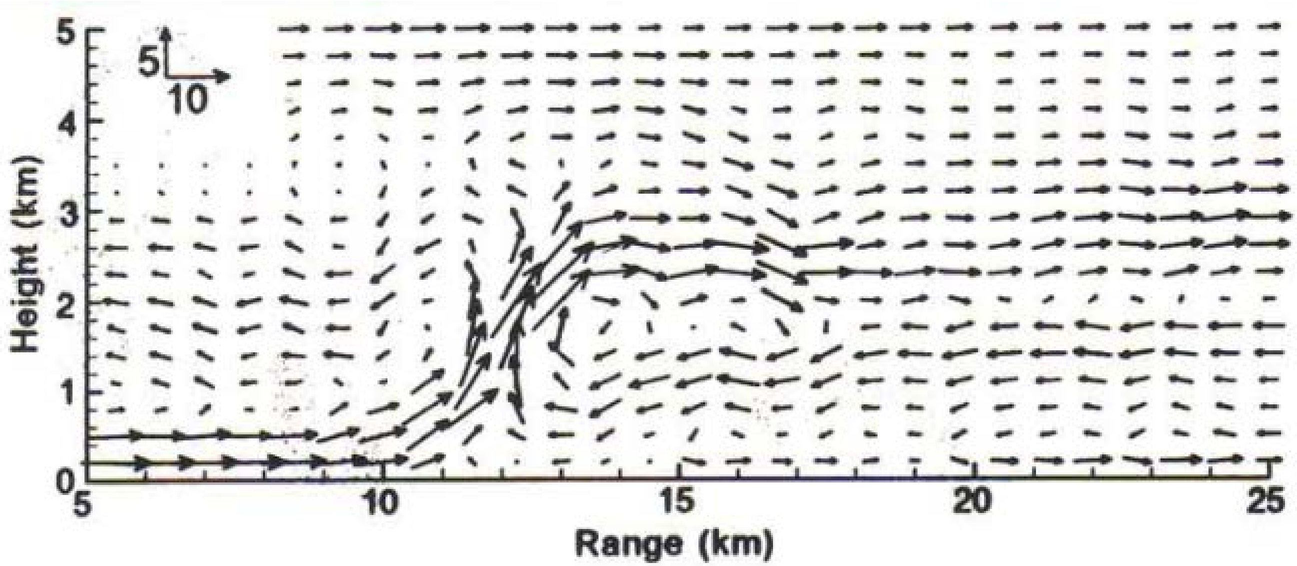




K. Browning



Assumption:
2-dimensional flow

Integration of horizontal convergence

Flow relative to frontal motion

Hagen, 1992

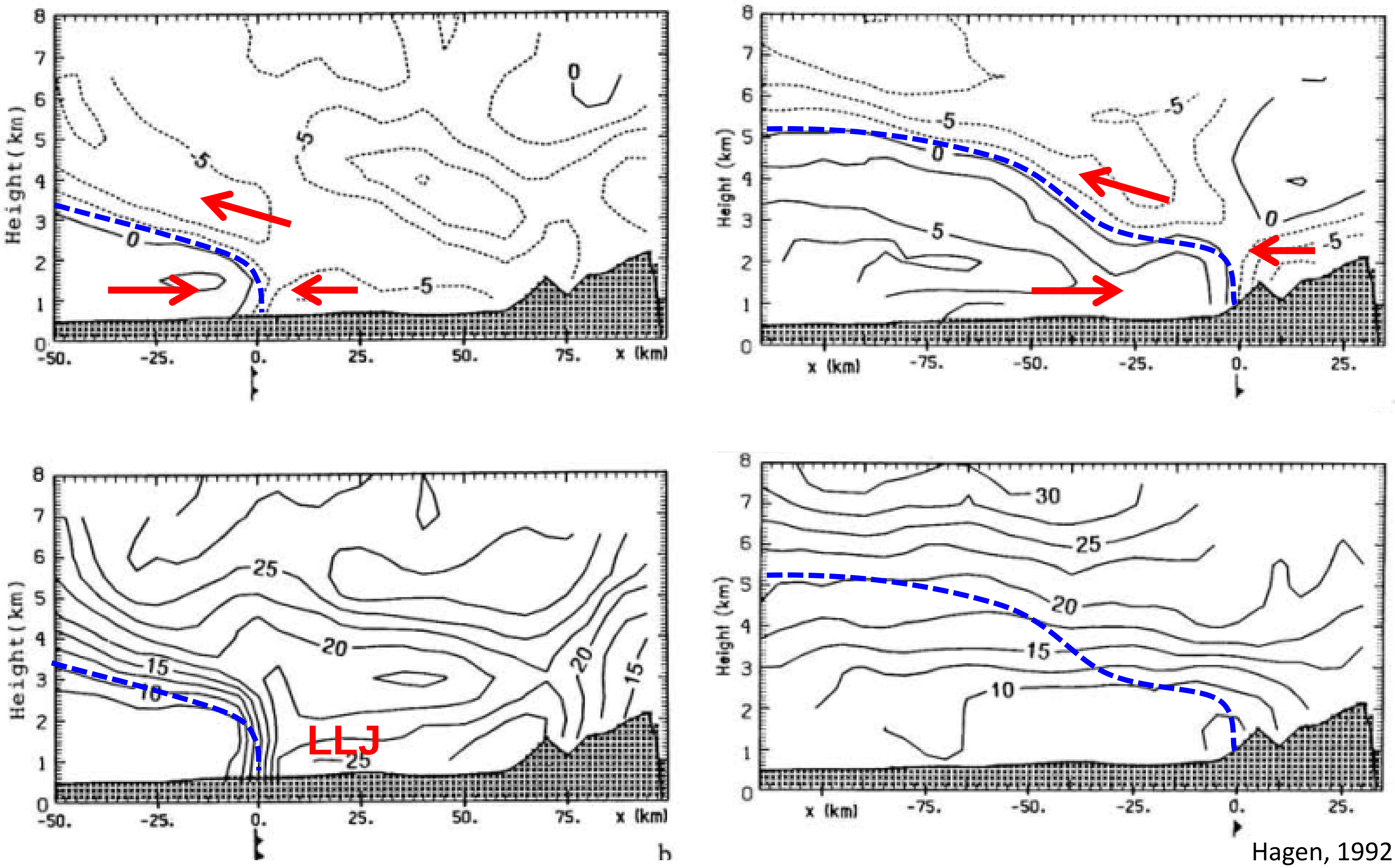
Narrow cold frontal rain band (18/19 Dec. 1987)

- 3-dimensional single-Doppler wind field estimation (UWT – ECUW)

01:21 UTC alpine foreland | 02:32 UTC over Alps

cross-frontal relative to propagation (u-c)

parallel front (v)



Hagen, 1992

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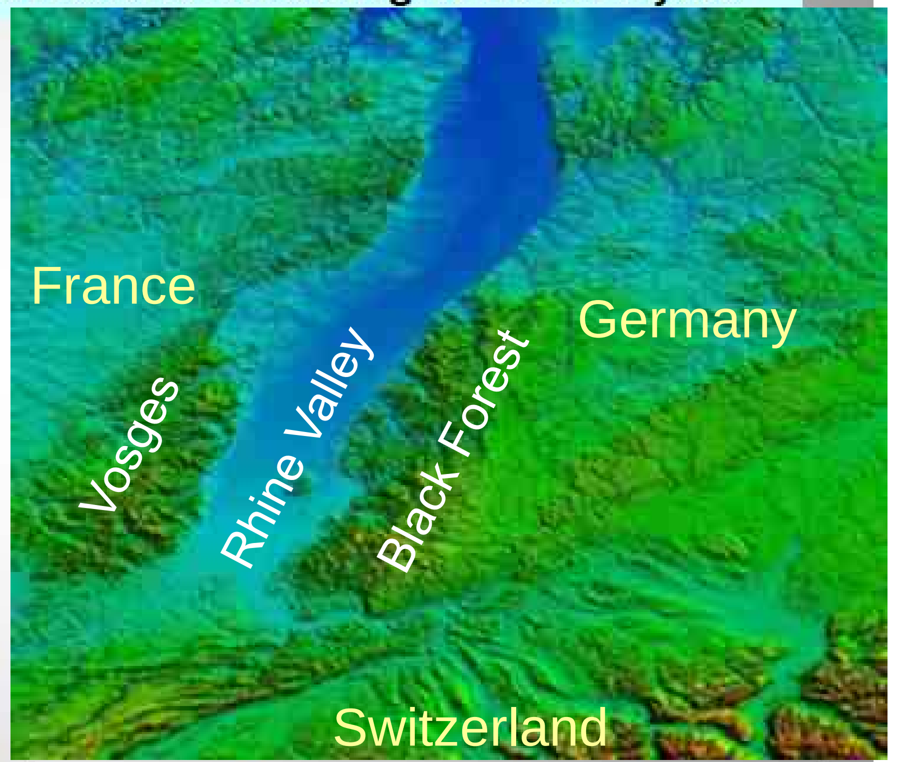
COPS (Convective and Orographically-induced Precipitation Study)

Summer 2007

Goal: Advance the quality of forecasts of orographically-induced convective precipitation by 4D observations and modeling of its life cycle



Bull. Amer. Meteor. Soc. 89(10), 1477-1486,
DOI:10.1175/2008BAMS2367.1.

V. Wulfmeyer October 27-29, 2008 7th COPS Workshop, Collège Doctoral Européen, Strasbourg, France

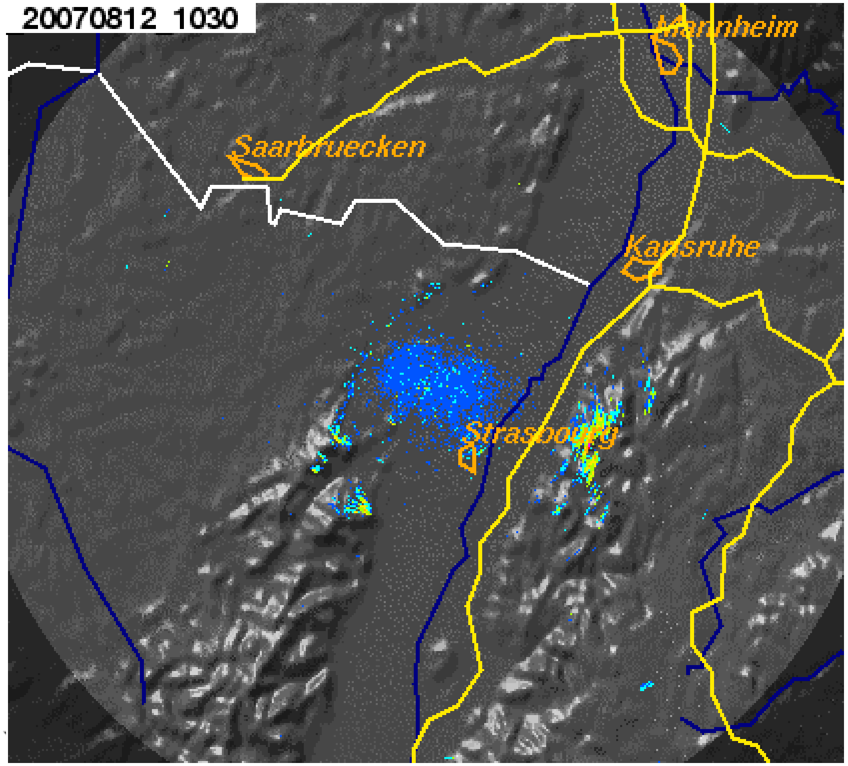
Mobile deployment of POLDIRAD at Waltenheim sur Zorn, Alsace, France

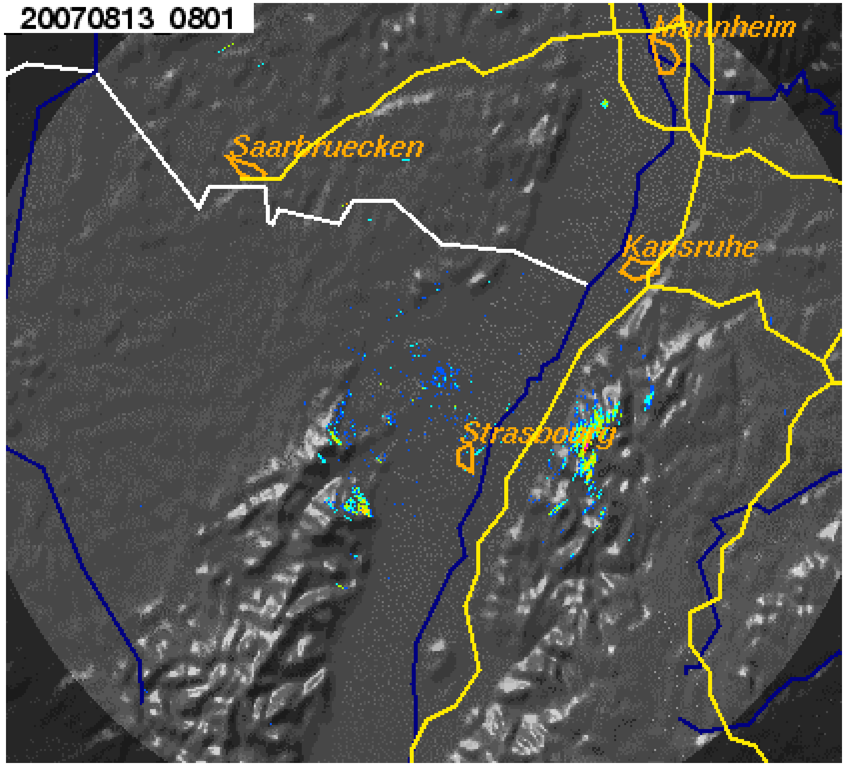
Photo: A. Behrendt

POLDIRAD observations during IOP 15 (daytime)

12 Aug. 2007 11-17 UTC 13 Aug. 2007 8-15 UTC

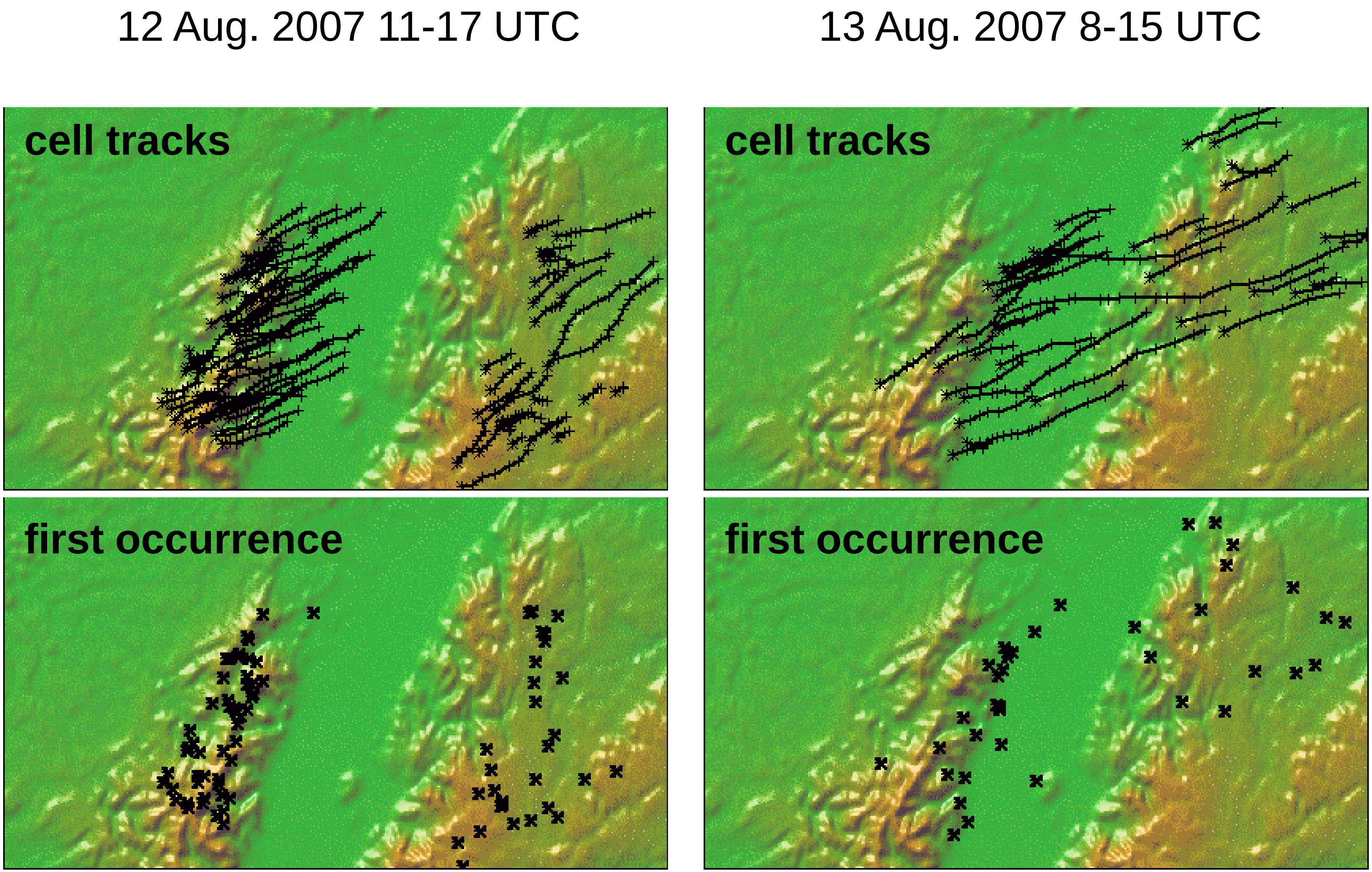
every 10 minutes





Hagen et al., 2011

Cell Tracking IOP 15 using POLDIRAD Observations

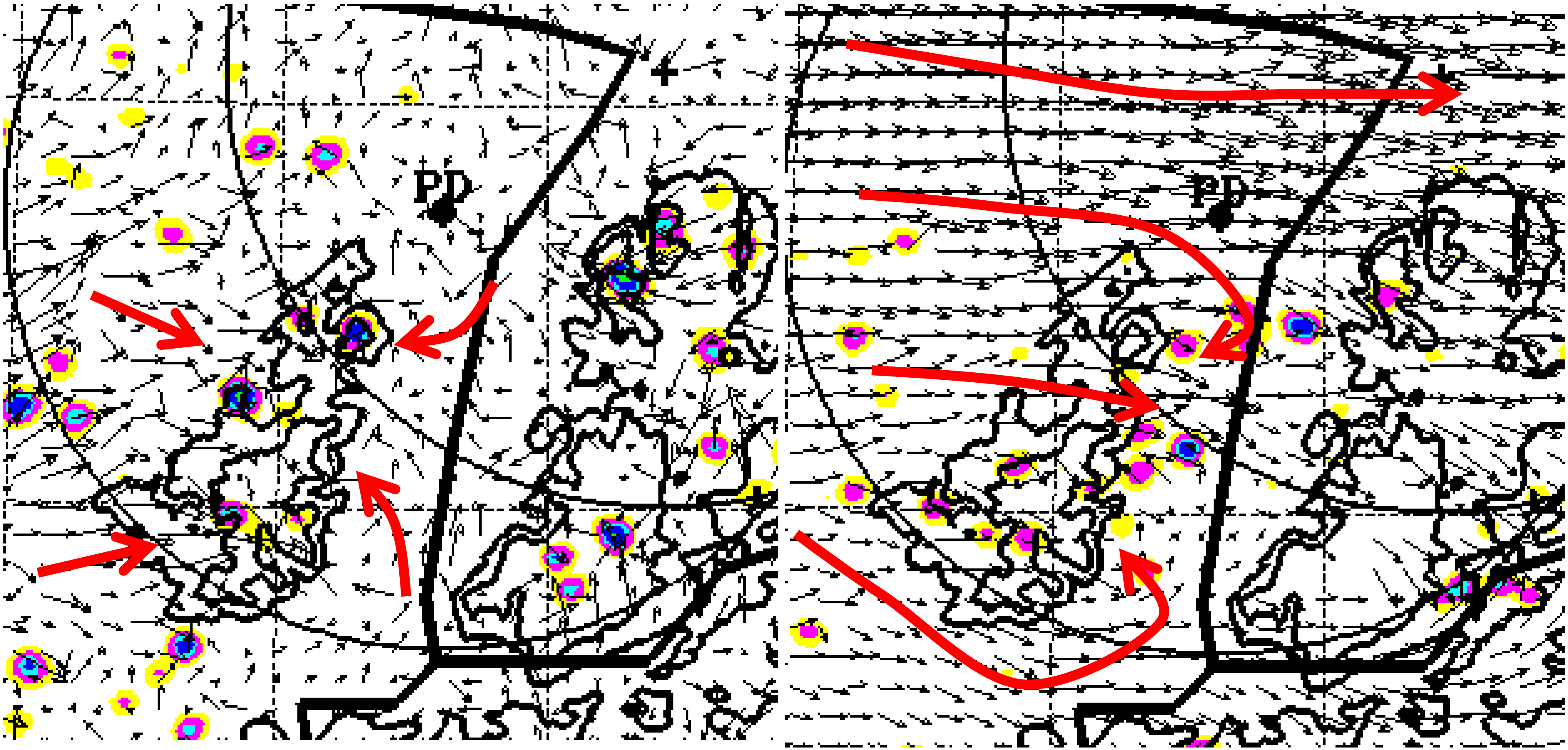


Hagen et al., 2011

MesoNH Simulations

wind field (at 1000m MSL) and rain rate

12 Aug. 2007 15 UTC 13 Aug. 2007 11 UTC



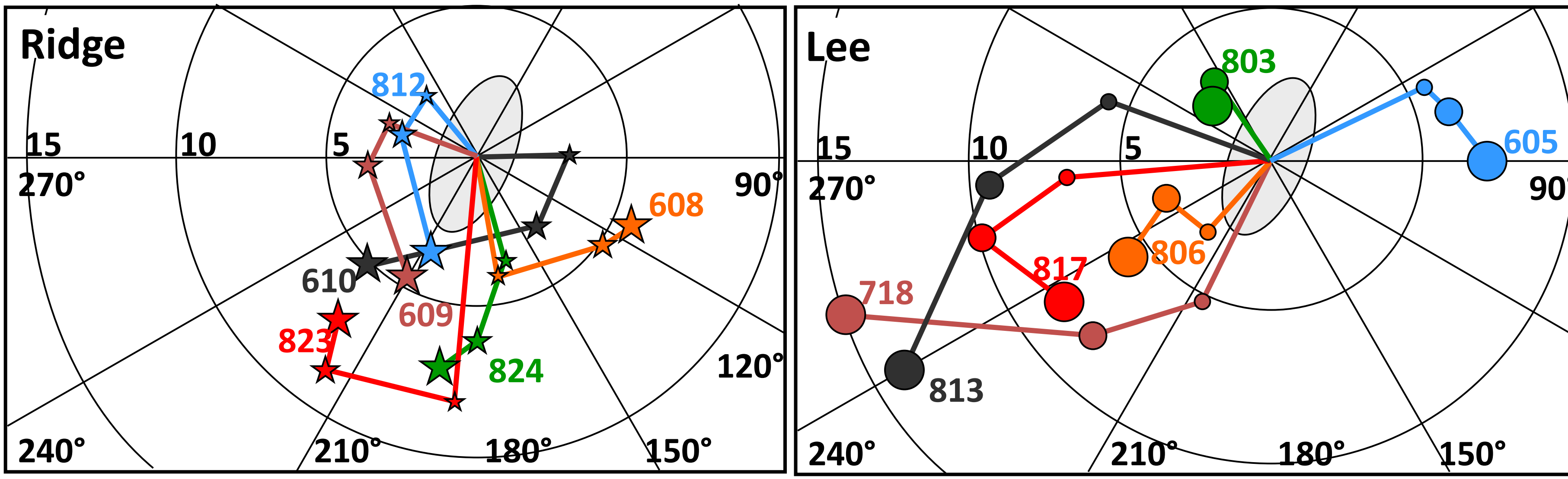
Hagen et al., 2011

Convective Hotspots in Mountainous Terrain

Major difference caused by the wind profile
(stratification is of minor relevance, same on both days)

Wind speed and direction (Nancy sounding, 925, 850 700 hPa)

6 days with initiation on the ridge 6 days with initiation on the lee side



Hagen et al., 2011

Convective Hotspots in Mountainous Terrain

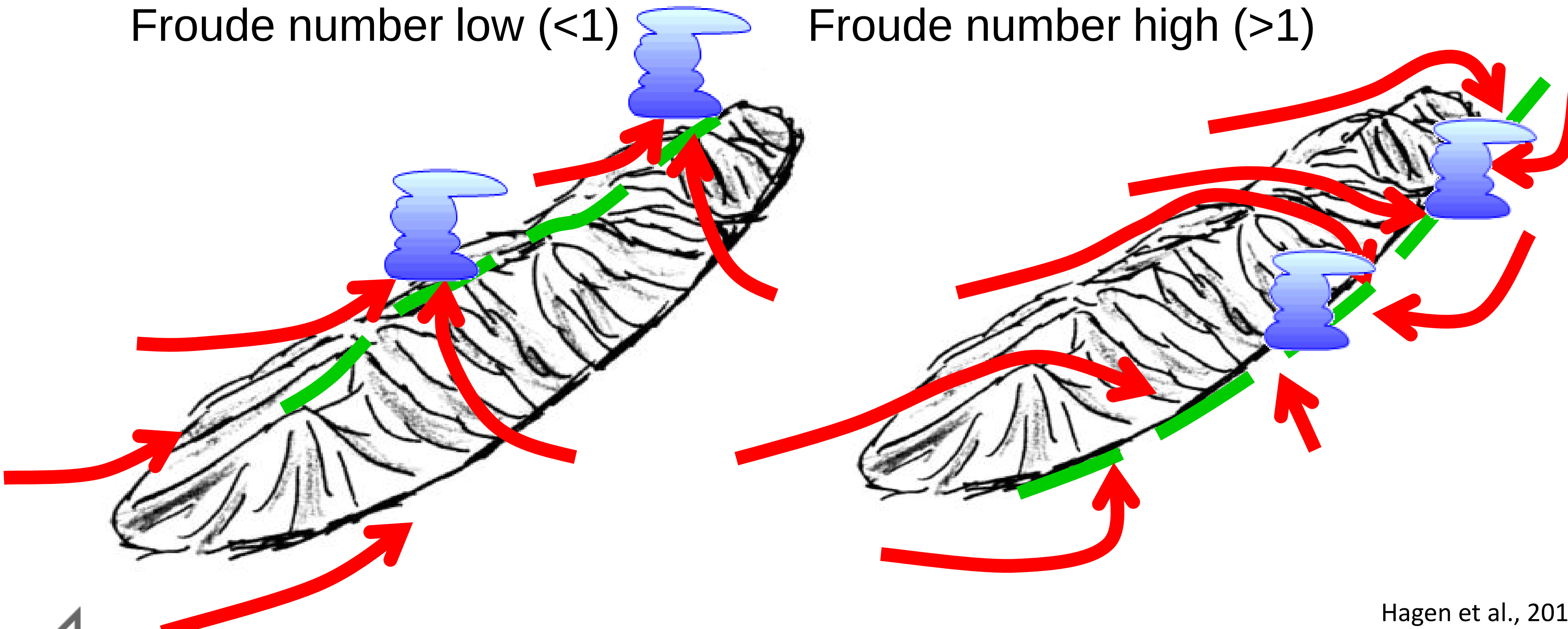
Major difference caused by the wind profile
(stratification is of minor relevance, same on both days)

ridge initiation
weak winds perpendicular or parallel to Vosges

Froude number low (<1)

lee initiation
strong winds from south-west around and over mountains

Froude number high (>1)



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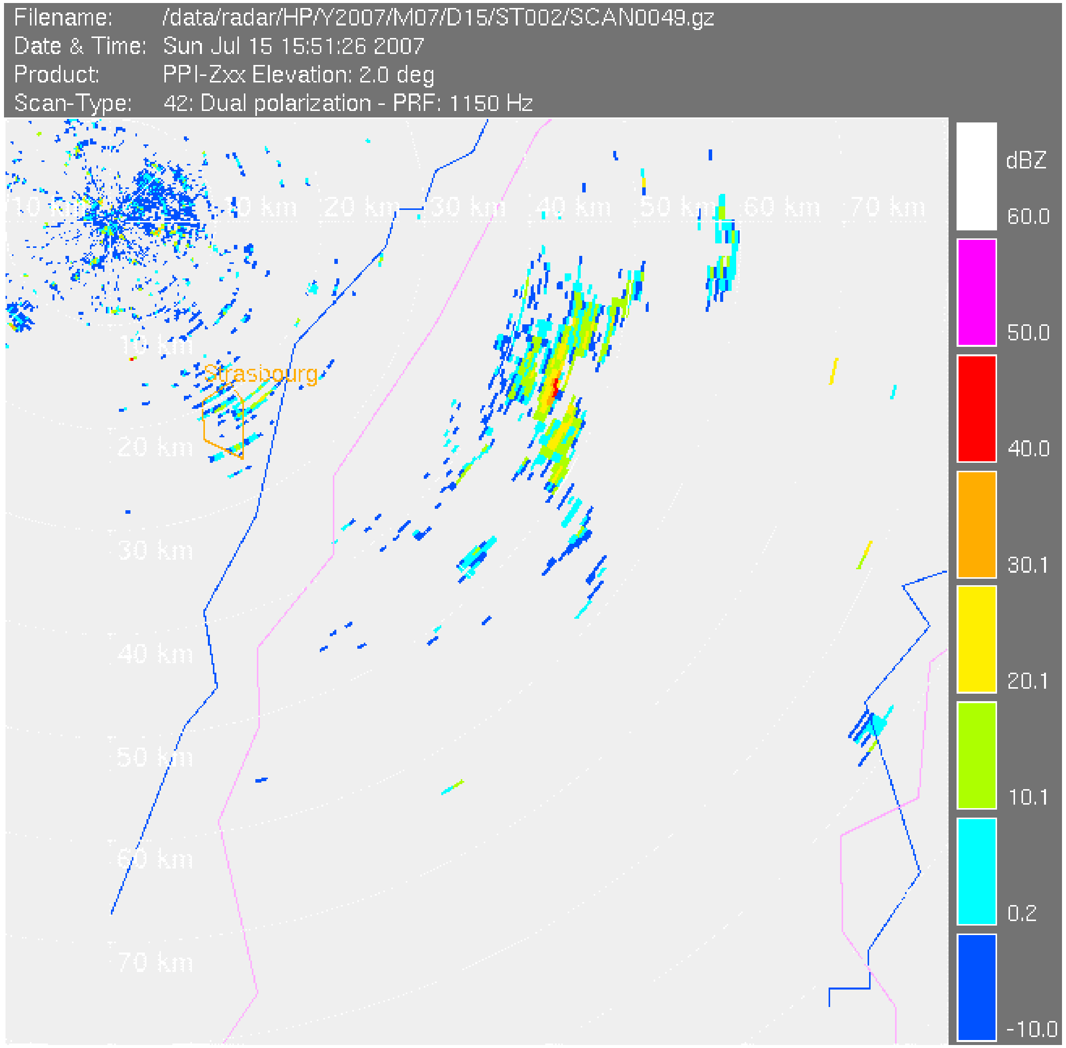
DLR

Isolated single cell in the lee of Black Forest

- Isolated single storm cell developed very rapidly at 14.30 UTC, 15 July 2007
- POLDIRAD radar reflectivity at 2° elevation every 10 min
- Cloud-to-ground (green) and intra-cloud (red) lightning only during the build-up phase
- Storm decayed rapidly after one hour

- most mesoscale NWP's failed to forecast deep convection



Hartmut Höller

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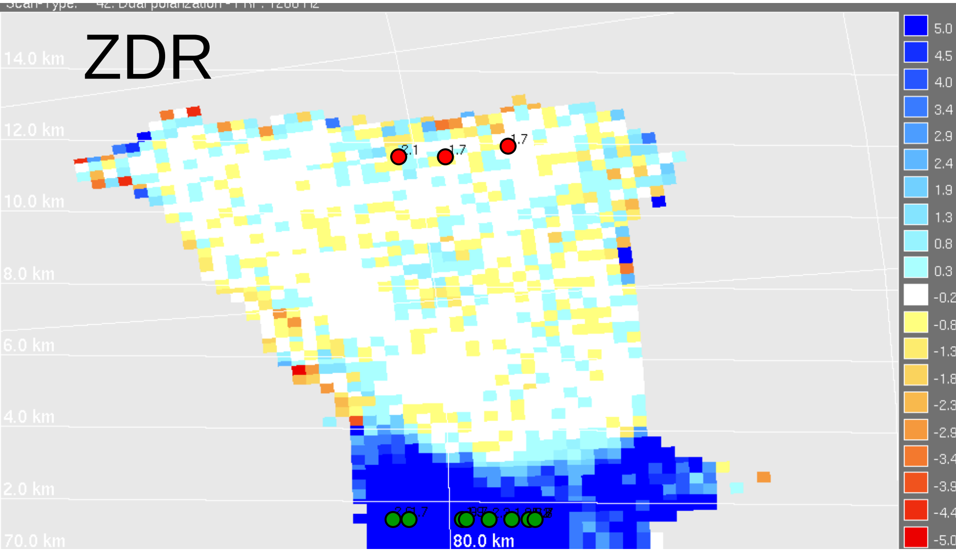
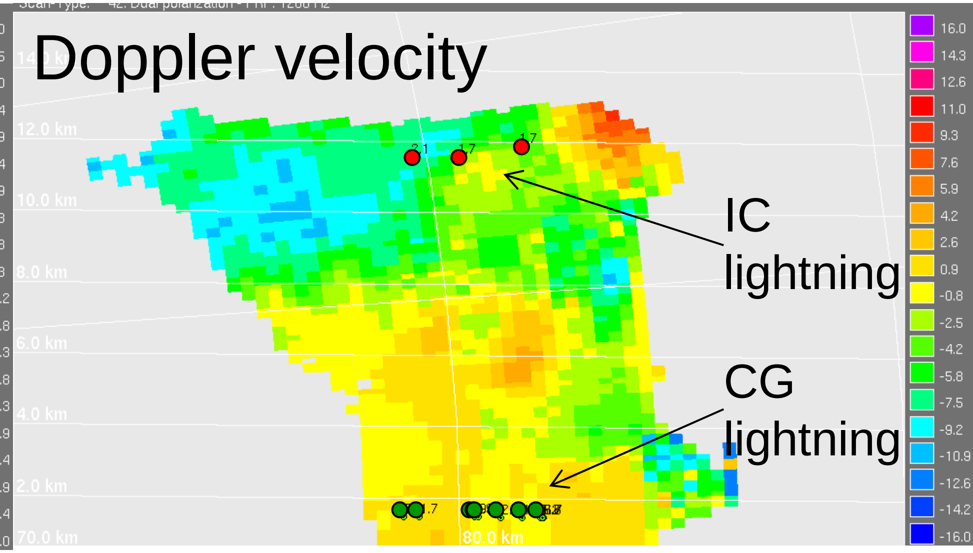
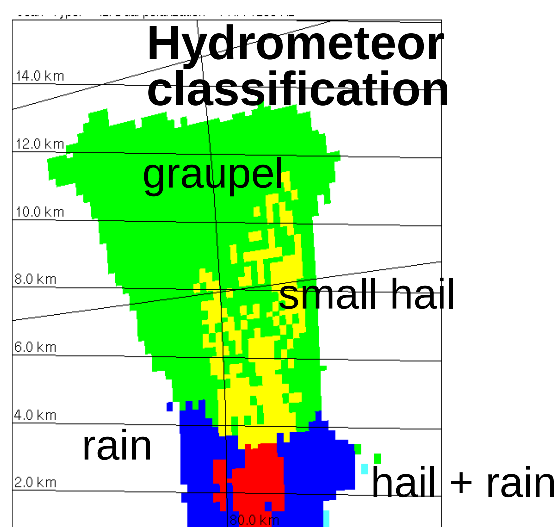




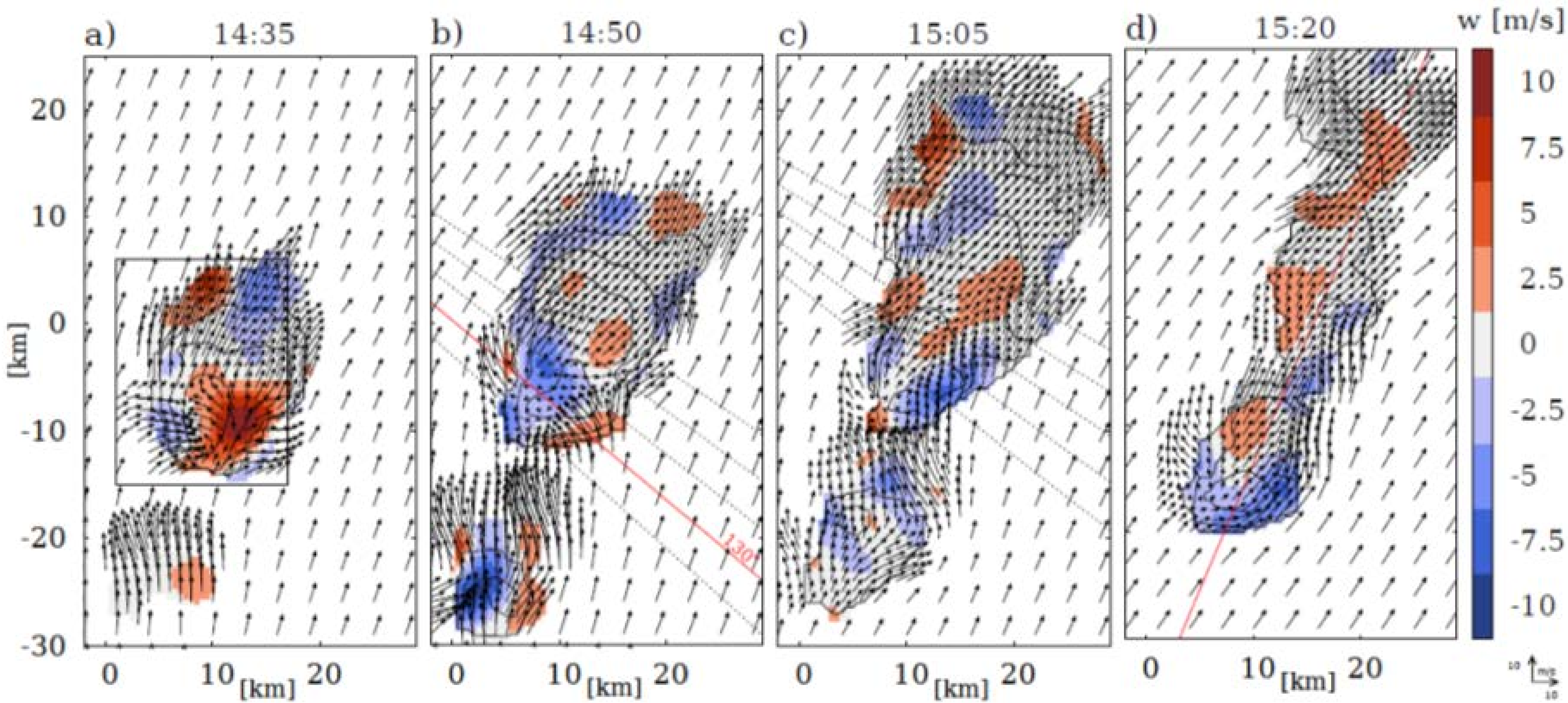
- Differential reflectivity (and hail spike) are indicators for hail
- Hail was reported at the surface
- Doppler velocity shows divergence in the anvil region



Hartmut Höller

Isolated single cell in the lee of Black Forest

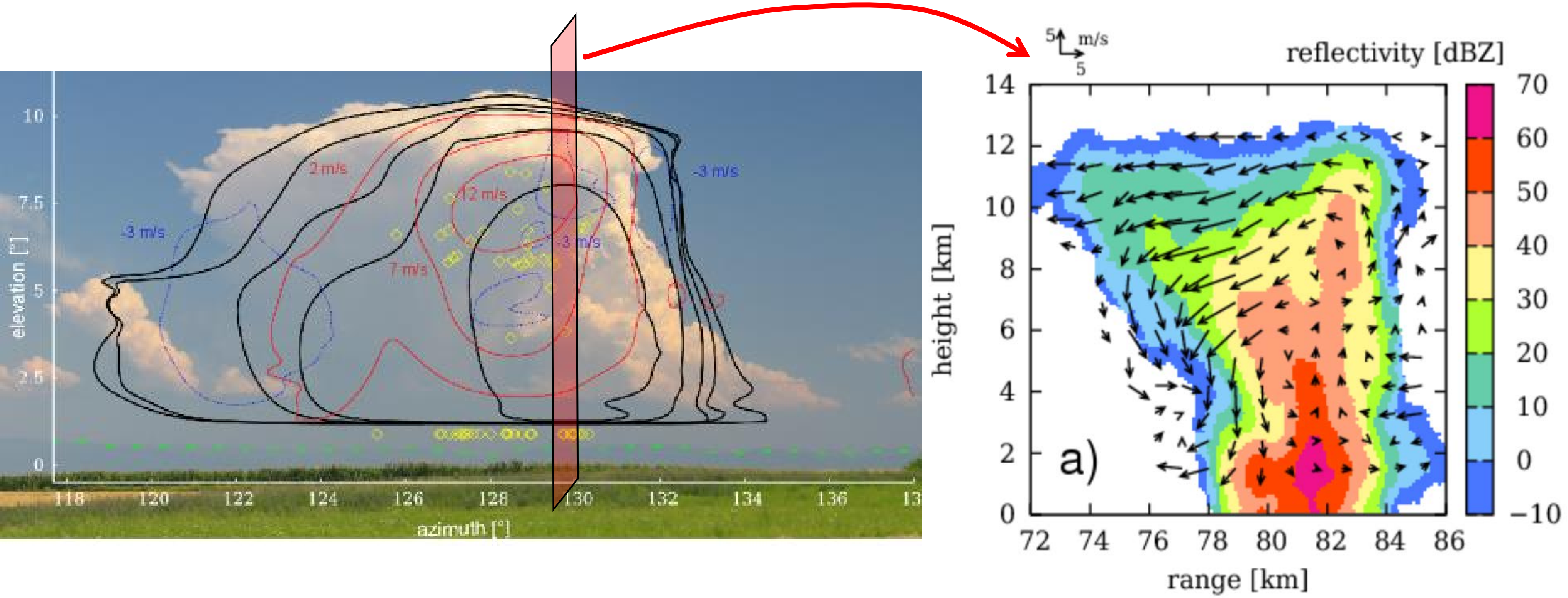
- 3D wind field from Triple-Doppler analysis
  (FZ Karlsruhe, DWD Feldberg, DWD Türkheim)



- vertical motion (colored) and horizontal wind vectors at 5 km MSL

Schmidt et al., 2012

Isolated single cell in the lee of Black Forest



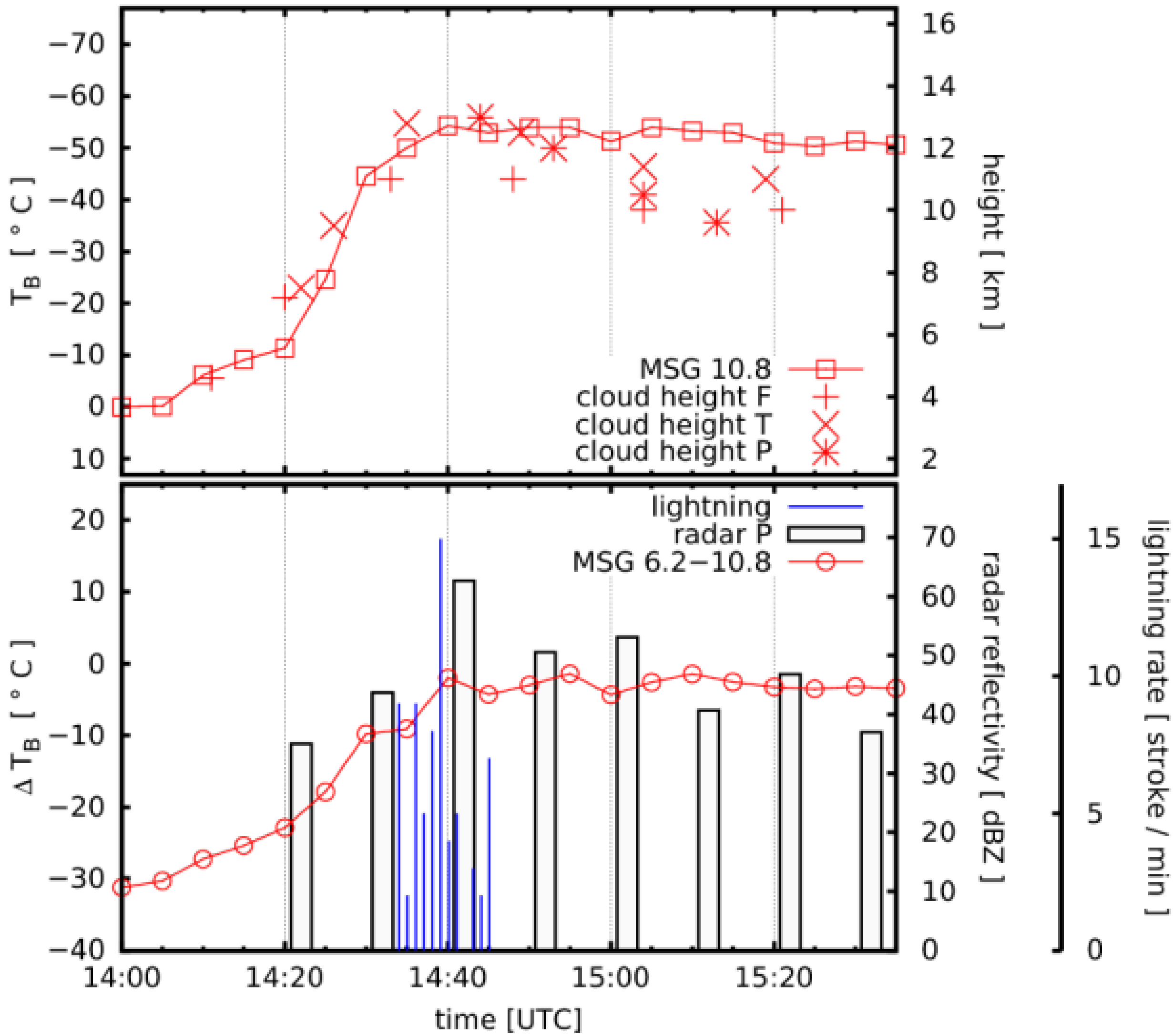
- 3D wind field from Triple-Doppler analysis (FZ Karlsruhe, DWD Feldberg, DWD Türkheim), Reflectivity and LINET lightning
- RHI: Reflectivity from POLDIRAD

Schmidt et al., 2012

Isolated single cell in the lee of Black Forest

Temporal development of

- MSG brightness temperatures
- echo top
- radar reflectivity
- flash rate



Schmidt et al., 2012

Conclusion

Dual-polarization Doppler weather radar are an essential tool for the investigation of mesoscale precipitation systems

- single Doppler wind field
- multiple Doppler wind field
- hydrometeor classification

Additional sensors like

- lightning detections system
- satellite (infrared or visible)

provide valuable additional information